

CLAIMS

1. An organic-inorganic hybrid material comprising two phases:

5           - a first, mineral phase comprising a structured mesoporous network with open porosity; and

          - a second, organic phase comprising an organic polymer, said organic phase being essentially not present inside the pores of the structured  
10 mesoporous network.

2. The material of claim 1, further comprising a third phase, inside the pores, composed of at least one surface active agent.

3. The material of claim 1, wherein the  
15 mineral phase and the organic phase are continuous and intermingled.

4. The material of claim 1, wherein the mineral phase is discontinuous and dispersed in the organic phase, which is continuous.

20           5. The material of any one of the preceding claims, wherein the mineral phase has conductive and/or hydrophilic functions on the surfaces of its pores.

          6. The material of any one of the preceding claims, wherein the organic phase has conductive and/or  
25 hydrophilic functions.

          7. The material of either of claims 5 and 6, wherein the third phase, composed of at least one surface active agent, has conductive and/or hydrophilic functions.

8. The material of claim 5 or 6, wherein said conductive functions are selected from cation exchange groups.

9. The material of claim 8, wherein said cation exchange groups are selected from the following groups:  $\text{SO}_3\text{M}$ ;  $-\text{PO}_3\text{M}_2$ ;  $-\text{COOM}$  and  $\text{B}(\text{OM})_2$ , where M represents hydrogen, a monovalent metal cation, or  $^+\text{NR}^1_4$ , where each  $\text{R}^1$ , independently, represents a hydrogen, an alkyl radical or an aryl radical.

10. The material of any one of claims 5 to 7, wherein said conductive functions are selected from anion exchange groups.

11. The material of claim 10, wherein said anion exchange groups are selected from the following groups: pyridyl, imidazolyl, pyrazolyl; triazolyl; the radicals of formula  $^+\text{NR}^2_3\text{X}^-$ , where X represents an anion such as, for example, F, Cl, Br, I,  $\text{NO}_3$ ,  $\text{SO}_4\text{H}$  or OR, R being an alkyl radical or an aryl radical, and where each  $\text{R}^2$ , independently, represents a hydrogen, an alkyl radical or an aryl radical; and the basic aromatic or nonaromatic radicals containing at least one radical selected from imidazole, vinylimidazole, pyrazole, oxazole, carbazole, indole, isoindole, dihydrooxazole, isoxazole, thiazole, benzothiazole, isothiazole, benzimidazole, indazole, 4,5-dihydropyrazole, 1,2,3-oxadiazole, furazan, 1,2,3-thiadiazole, 1,2,4-thiadiazole, 1,2,3-benzotriazole, 1,2,4-triazole, tetrazole, pyrrole, aniline, pyrrolidine, and pyrazole radicals.

12. The material of any one of the preceding claims, wherein the mineral phase is composed

of at least one oxide selected from metal oxides, metalloid oxides and mixed oxides thereof.

13. The material of claim 12, wherein said oxide is selected from the oxides of silicon, titanium, zirconium, hafnium, aluminum, tantalum, tin, rare earths such as europium, cerium, lanthanum, and gadolinium, and mixed oxides thereof.

14. The material of any one of the preceding claims, wherein the mesoporous network has an organized structure with a repeating unit.

15. The material of claim 14, wherein the mesoporous network has a cubic, hexagonal, lamellar, vermicular, vesicular or bicontinuous structure.

16. The material of any one of the preceding claims, wherein the size of the pores is from 1 to 100 nm, preferably from 1 to 50 nm.

17. The material of any one of the preceding claims, wherein the organic polymer is a thermally stable polymer.

18. The material of claim 17, wherein the organic polymer is selected from polyetherketones (PEK, PEEK, PEEKK); polysulfones (PSU); polyethersulfones; polyphenylethersulfones (PPSU); styrene/ethylene (SES), styrene/butadiene (SBS), and styrene/isoprene (SIS) copolymers; polyphenylenes, such as poly(phenylene sulfide)s and poly(phenylene oxide)s; polyimidazoles, such as polybenzimidazoles (PBI); polyimides (PI); polyamideimides (PAI); polyanilines; polypyrroles; polysulfonamides; polypyrazoles, such as polybenzopyrazoles; polyoxazoles, such as polybenzoxazoles; polyethers, such as poly(tetramethylene oxide)s and

poly(hexamethylene oxide)s; poly((meth)acrylic acid)s; polyacrylamides; polyvinyls, such as poly(vinyl ester)s, for example, polyvinyl acetates, polyvinyl formates, polyvinyl propionates, polyvinyl laurates, 5 polyvinyl palmitates, polyvinyl stearates, polyvinyl trimethylacetates, polyvinyl chloroacetates, polyvinyl trichloroacetates, polyvinyl trifluoroacetates, polyvinyl benzoates, polyvinyl pivalates, and polyvinyl alcohols; acetal resins, such as polyvinyl butyrals; 10 polyvinylpyridines; polyvinylpyrrolidones; polyolefins, such as polyethylenes, polypropylenes, and polyisobutylenes; poly(styrene oxide)s; fluoro resins and polyperfluorocarbons, such as polytetrafluoroethylenes (PTFE); poly(vinylidene fluoride)s (PVDF); 15 polychlorotrifluoroethylenes (PCTFE); polyhexafluoropropenes (HFP); perfluoroalkoxides (PFA); polyphosphazenes; silicone elastomers; and block copolymers comprising at least one block composed of a polymer selected from the above polymers.

20 19. The material of any one of claims 2 to 18, wherein the surface active agent is selected from: surfactants such as alkyltrimethylammonium salts, alkyl phosphate salts and alkylsulfonate salts; acids such as dibenzoyltartaric acid, maleic acid or long-chain fatty 25 acids; bases such as urea or long-chain amines; phospholipids; doubly hydrophilic copolymers whose amphiphilicity is generated in situ by interaction with a substrate; and amphiphilic multiblock copolymers comprising at least one hydrophobic block in 30 combination with at least one hydrophilic block.

20. A membrane comprising the material of any one of the preceding claims, optionally deposited on a support.

21. An electrode comprising the material of  
5 any one of claims 1 to 19.

22. A fuel cell comprising at least one membrane of claim 20 and/or electrode of claim 21.

23. A process for preparing the material of any one of claims 1 to 19, wherein the following steps  
10 are realized:

a) - a solution is prepared, in a solvent, of a mineral precursor A intended to constitute the mesoporous mineral phase, and optionally this solution is hydrolyzed and allowed to age;

15 b) a solution is prepared, in a solvent, of a surface active agent D, a templating, texturizing agent for the mesoporous mineral phase;

c) - a solution is prepared, in a solvent, of an organic polymer E;

20 d) - at the end of steps a), b) and c), the solution of templating agent D is added to the solution of organic polymer E and homogeneization is carried out, and then the solution of mineral precursor A is added with stirring to the resultant mixture of the  
25 solutions of surface active agent D and of organic polymer E; or else

the solution of precursor A is added to the solution of surface active agent D and homogeneization is carried out, and then the solution of organic  
30 polymer E is added with stirring; or else

the solution of precursor A is added to the solution of organic polymer E and homogeneization is carried out, and then the solution of surface active agent D is added with stirring;

5                   whereby an organic-inorganic hybrid solution is obtained ;

and the resultant organic-inorganic hybrid solution is optionally allowed to age;

10                   e) - the organic-inorganic hybrid solution is deposited or impregnated on a support;

f) - solvents are evaporated under controlled pressure, temperature, and humidity conditions;

15                   g) - a heat treatment is carried out to consolidate the deposited or impregnated material;

h) - the surface active agent D is optionally removed completely or partially;

i) - the support is separated or removed, optionally.

20                   24. The process of claim 23, wherein a chelating agent B is further added to the solution of mineral precursor A.

25                   25. The process of either of claims 23 and 24, wherein, to the solution of mineral precursor A, , a compound C is further added which carries, on the one hand, conductive and/or hydrophilic functions and/or precursor functions of conductive and/or hydrophilic functions, and, on the other hand, functions capable of undergoing bonding to the surface of the pores of the  
30                   mesoporous network.

26. The process of any one of claims 23 to 25, wherein the process further comprises a final step of treatment to liberate or generate conductive and/or hydrophilic functions on the surface of the pores of the material.

27. The process of any one of claims 23 to 26, wherein the solution A is left to age at a temperature of 0°C to 300°C, preferably of 20°C to 200°C; at a pressure of 100 Pa to  $5 \cdot 10^6$  Pa, preferably of 1000 Pa to  $2 \cdot 10^5$  Pa; for a time of a few minutes to a few days, preferably of one hour to one week.

28. The process of any one of claims 23 to 27, wherein the organic-inorganic hybrid solution obtained in step d) is left to age at a temperature of 0 to 300°C, preferably of 20°C to 200°C; at a pressure of 100 Pa to  $5 \cdot 10^6$  Pa, preferably of 1000 Pa to  $2 \cdot 10^5$  Pa; for a time of a few minutes to a few days, preferably of one hour to one week.

29. The process of any one of claims 23 to 28, wherein the solvents are evaporated at a temperature of 0 to 300°C, preferably of 10°C to 160°C; at a relative humidity (RH) of 0 to 100%, preferably of 20% to 95%.

30. The process of any one of claims 23 to 29, wherein, in step e), the organic-inorganic hybrid solution is deposited or impregnated on a support by a method selected from the method of deposition by centrifugal coating known as spin coating, the method of deposition by immersion and withdrawal known as dip coating, the method of deposition by laminar coating known as meniscus coating, the method of deposition by

spraying known as "spray coating", the method of deposition by casting and the method of deposition by evaporation.